An Object-Based Software Framework: Application to Sustainable Military Environmental Management

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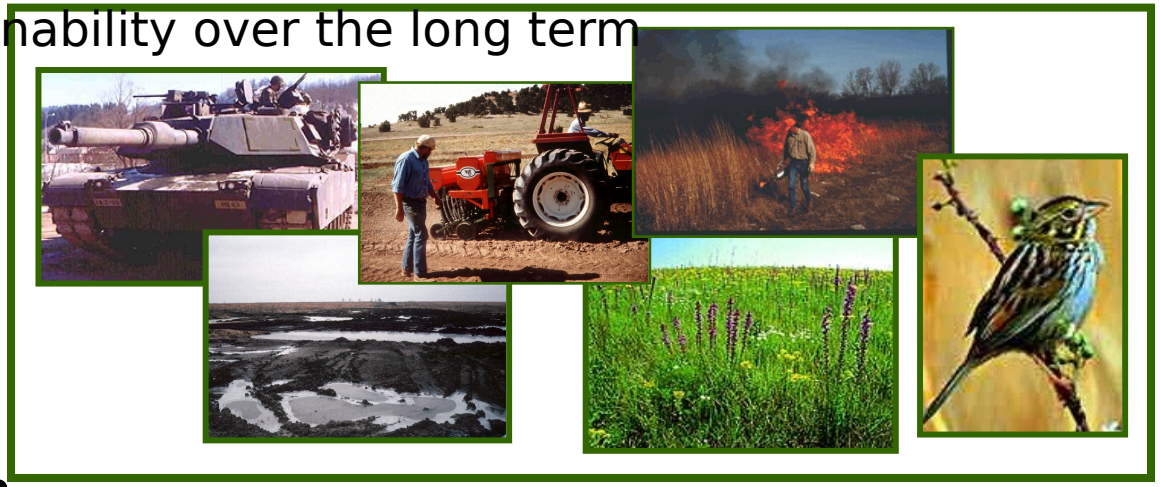
11th Annual ITAM Workshop
Savannah, GA
August 19 – 23, 2002

Military Balances Multiple Land Management Objectives

- **Military land managers and decision makers are required to:**
  - Balance maximum flexibility for the mission with a multitude of other land use and land management goals
  - Utilize integrated natural resource planning and ecosystem management approaches to maintain ecosystem health and sustainability over the long term

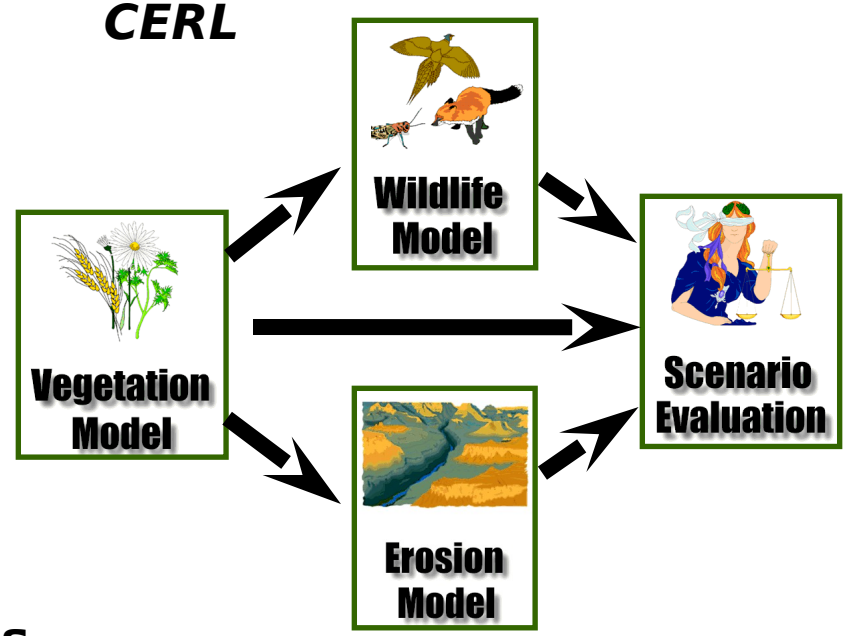


- **Solution**
  - Develop and deliver an easy-to-use integrated dynamic modeling and decision-support technology to offer a long-term strategic approach for land resource management

Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS)

- **The central component of IDLAMS is a vegetation (land cover) change model, which incorporates changes due to:**
  - natural succession
  - land use impacts
  - resource management actions
- **Other management concerns modeled and linked to the vegetation dynamics model are:**
  - wildlife
  - soil erosion
- **Decision analysis methods and technologies are used to perform trade-off analyses on spatially explicit modeling results**

- ***Funded by Fort Riley, Kansas and SERDP***
- ***SERDP research was a partnership with ERDC-CERL***



Integration accomplished through a GIS framework

IDLAMS Prototype Migrates to Object-Oriented Architecture

- **Although still utilizing GIS, new approach uses an object-oriented framework called the Dynamic Information Architecture System (DIAS) to integrate the models.**
- **DIAS, an ANL-developed object-based software *framework* for modeling and simulation:**
  - A software framework for building process-based discrete event simulations and decision support applications
  - Completely object-based and distributed
  - Domain-neutral (not tied to a specific discipline or subject area)
  - Under development at ANL/DIS since 1993
  - Implementation in Java

Web Site: http://www.dis.anl.gov/DIAS

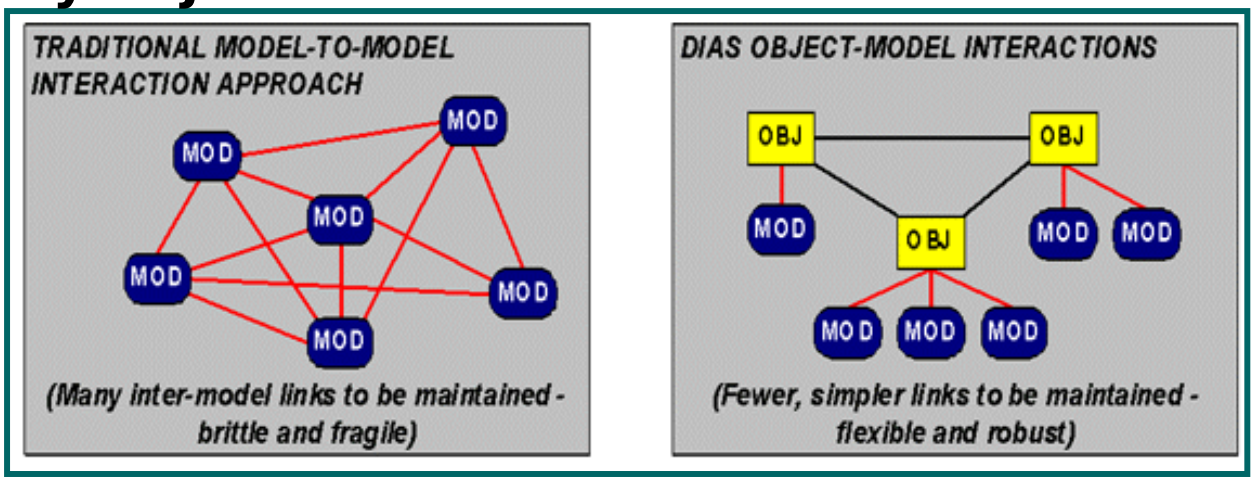
DYNAMIC INFORMATION ARCHITECTURE SYSTEM

Dynamic Information Architecture System (DIAS)

- **DIAS object-oriented approach used for model integration because:**
  - Develops flexible and adaptive mechanisms for integrating disparate existing software applications
  - Improves the ability to reflect the dynamics of living ecosystems, land uses, and land management practices
  - Supports software applications that operate at multiple spatial and temporal scales
  - Reduces the long-term cost of modeling technologies by using and reusing existing data, models, and system components

DIAS Entity-Centric Design

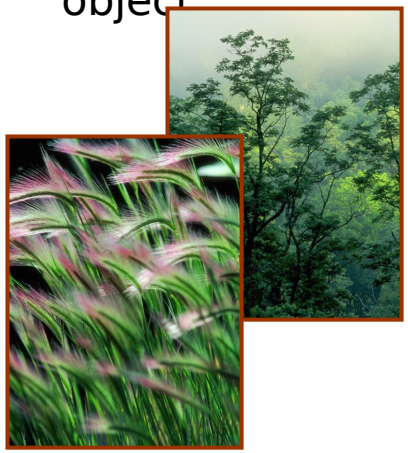
- **The main components of any DIAS simulation are:**
  - Software objects (Domain objects) that represent the real-world entities that comprise the problem space
  - Simulation models and other applications that express the dynamic behaviors of the domain entities
- **Models and applications running in a DIAS-based simulation interact indirectly with one another via Entity objects**



What is an Object-Oriented Approach?

- **An object receives and sends messages and contains programming code called a method (describing how the object should behave) and data (information that describes the object).**
- **DIAS "Domain" objects carry both:**
  - ***Parameters (State)*** - properties of an object and the current value of these properties
  - ***Aspects (Behavior)*** - how an object acts and reacts in terms of its state changes and through methods (functions) associated with the object

Conceptual Vegetation Domain Object



Design

Parameters (State)
- Leaf Area Index
- Patch Size
- Root Length Density
- Roughness Indices
- Stomatal Resistance
- Canopy and Ground Cover
- Successional Stage
- Total Biomass

Aspects (Behavior)

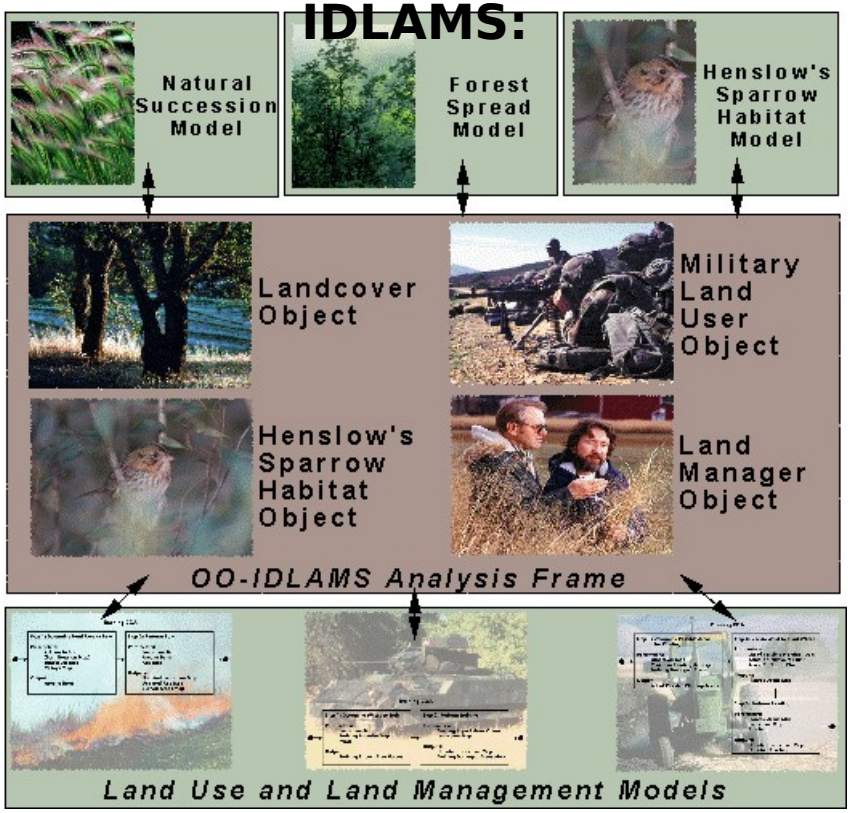
Local
- Seed Dispersal
- Water Use

Regional
- Fragmentation
- Evapotranspiration

Global
- Carbon Cycle
- Total Biomass
- Production

OO-IDLAMS Prototype Model Suite: Developed Using DIAS

OO-IDLAMS integrates a subset of the original IDLAMS:



- **Vegetation Dynamics Model**
  - Represents natural physical succession AND forest spread processes
- **Henslow's Sparrow Habitat Model**
  - Reimplemented as an Environmental Systems Research Institute (ESRI®) application
- **Military Training and Land Management Models**
  - Represents Fort Riley land use and land management plans: Training, Burning and Planting

OO-IDLAMS Prototype: Example Entity Object

Landcover Entity Object

State variables:

- ***Landcover map*** – Spatial Data Set (SDS) object that holds attributes for landcover categories
- ***Valleys map*** - SDS object that defines where valleys exist
- ***Successional time-step map*** - SDS object that holds the successional time-step
- ***Areas impacted by training map*** -SDS object that holds the output from Training Model
- ***Burned areas map*** - SDS object that holds output from Burning Model
- ***Years since burned*** - SDS object that holds the years since last burn
- ***Planted areas map*** – SDS object that holds output from Planting

Behavior:

- ***Implement forest spread process***-implements the forest spread process of the Vegetation Dynamics Model
- ***Implement succession process*** -implements the natural succession process of the Vegetation Dynamics Model

OO-IDLAMS Prototype: Land Use/Management Models

- **DIAS models were implemented to replace land use and land management components of original IDLAMS Vegetation Dynamics Model:**

Training Model *

- How much training impact
- Where training impact happens

* *Adapted from Army Training and Testing Area Carrying Capacity (ATTACC) methodology*

Planting Model

- What to plant
- How much to plant
- Where to plant

Burning Model

- How much to burn
- Where to burn

OO- IDLAMS Prototype: Henslow's Sparrow Habitat Model

- **The Henlow's Sparrow Habitat Model reimplemented as an Environmental Systems Research Institute (ESRI®) application**
- **Determines Henslow's Habitat Suitability bas**

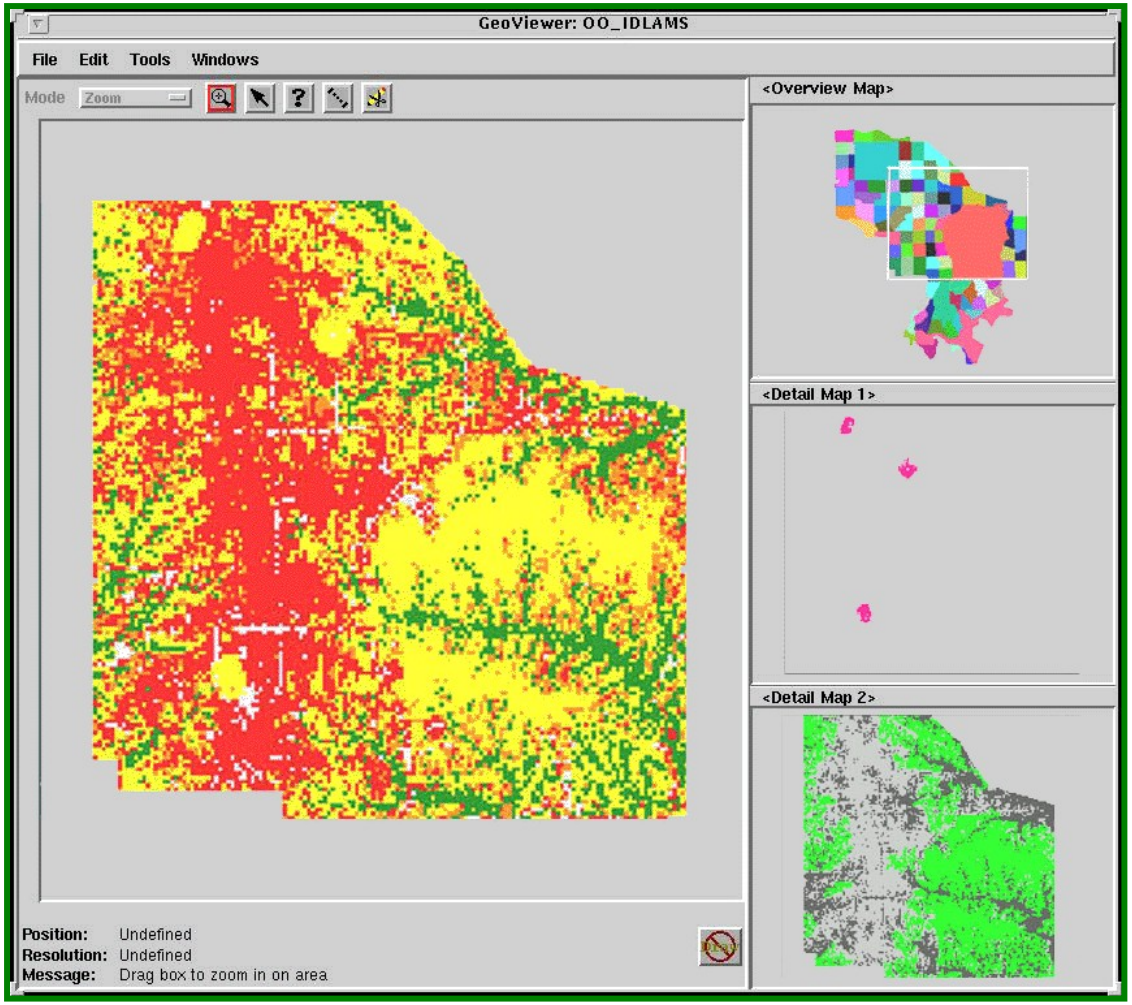
Burn history

- Henslow's habitat is poor for the first 2-3 years following a burn
- Dynamically operates on current burn map generated by the Burning Model

Patch size

- Henslow's requires 65-hectare patches of good/fair grasslands
- Can influence the Planting Model

GeoViewer Used to Dynamically View Multiple Aspects of the Simulation



Avian Population Dynamics Model for the Red-cockaded Woodpecker

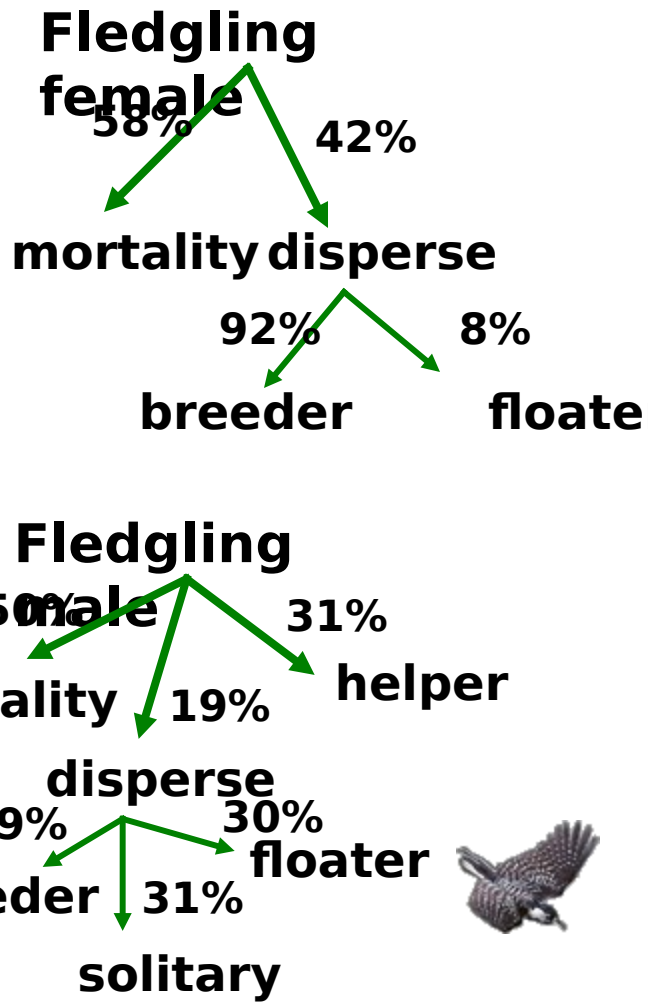
- **Sponsor: USACE, Engineer Research & Development Center (ERDC) – Construction Engineering Research Laboratory (CERL) and Fort Benning, GA**

Photographed by Derrick Hamrick
National Wildlife Federation: http://www.nwf.org

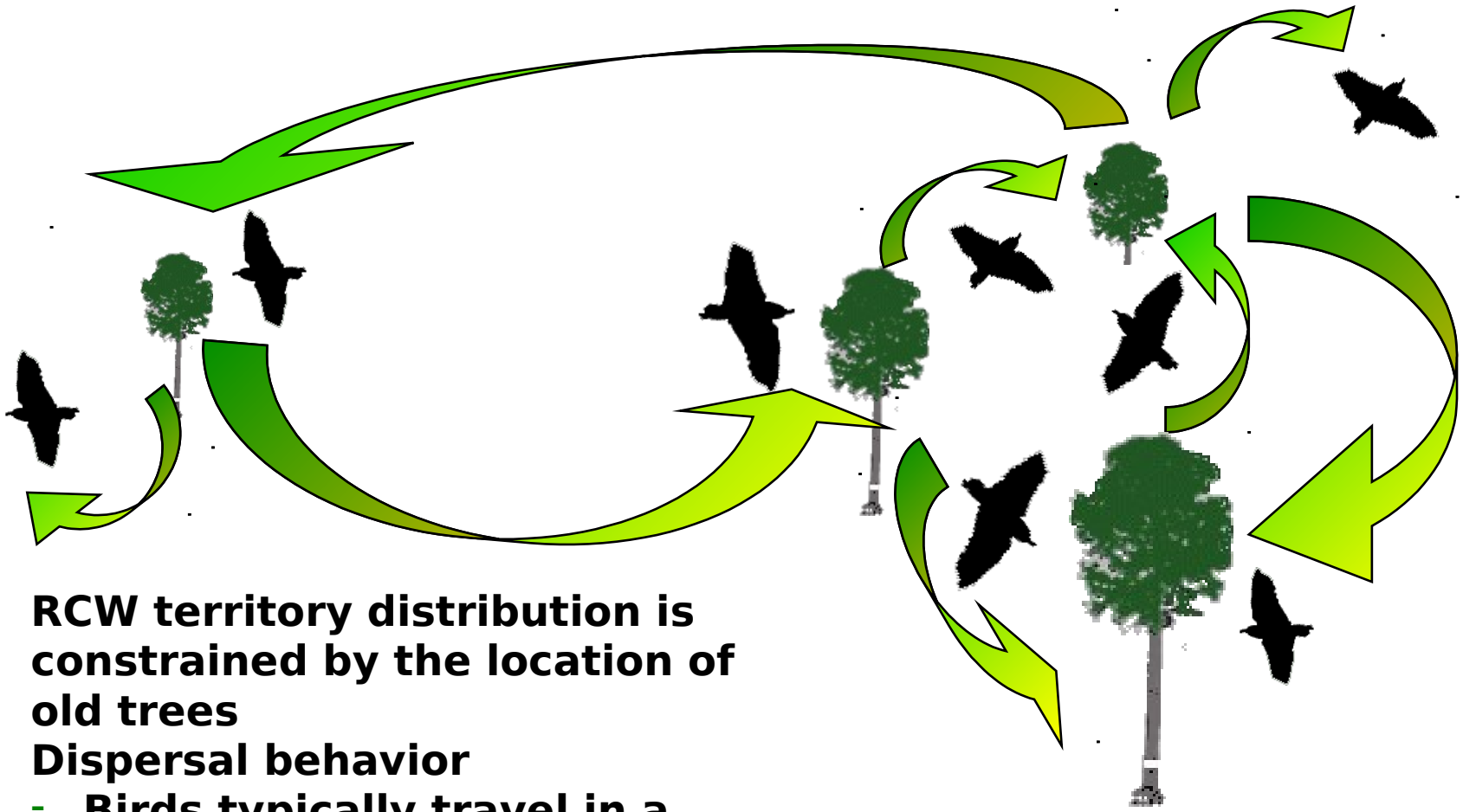
  - Implement an agent-based, spatially explicit population model for the RCW based on published model by Letcher et al. (1998)
  - Implement the RCW model generically within an object-oriented framework (Dynamic Information Architecture System [DIAS]), which can provide:
    - Reuse
    - Modularity
    - Expandability
    - Integration with other models

The RCW Has a Unique Cooperative Breeding Behavior

The RCW prefers longleaf pines >85 years of age for cavity excavation



Spatial Distribution of Territories Is Important in the Population Dynamics of the RCW



- RCW territory distribution is constrained by the location of old trees
- Dispersal behavior
  - Birds typically travel in a consistent dispersal direction and can travel 2.3 - 5.1 km per

RCW Domain Objects

RCW Individual

Attributes:

- Gender
- Age
- Location
- Territory *(can be nil)*
- Status (Role)
- Population

Behaviors:

- Dispersal
- Mortality
- Fledgling Role Change

RCW Population

Attributes:

- Members *(list of all RCWs)*
- Annual mortality rates
- Fecundity model coefficients
- Dispersal parameters

Behaviors:

- Female and Male Social Competition
- Breeding pair behavior

RCW Territory

Attributes:

- Location
- Condition/quality metrics *(future)*
- Fledglings
- Principal male
- Principal female
- Helpers
- Time since last occupied

Behaviors could include:

- *Dynamics of condition*
- *Quality of habitat*
- *Impacts of military land use*
- *Benefits of management intervention*

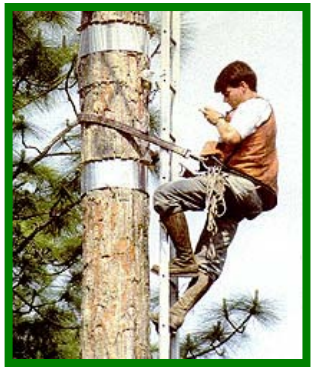
User Site (Fort Benning, GA) Requests Incorporation of RCW Management Actions

- **Fort Benning requested additional model functionality that reflects the management practices for the RCW**
- **The Land Manager object that was created has the following behaviors:**

Recruitment

Model now includes an algorithm for placing artificial nest boxes

- At least 10 acres
- Appropriate age and forest type
- Proximity to existing clusters

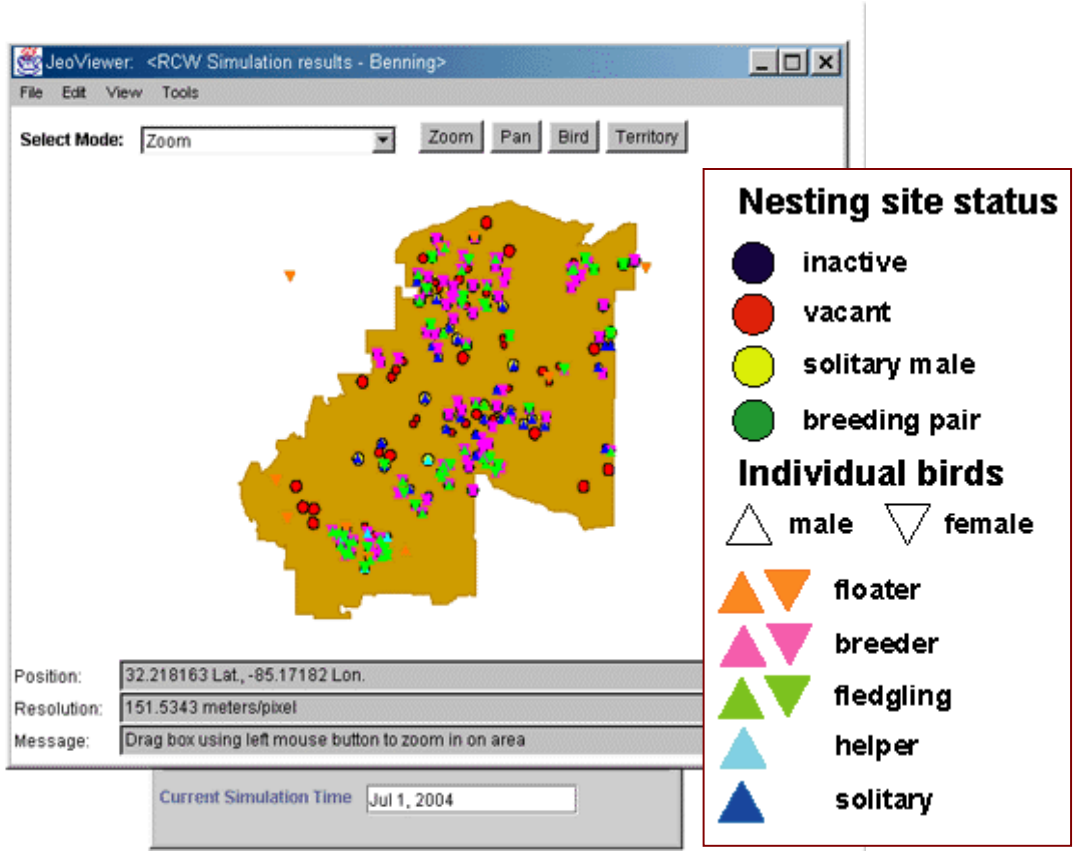


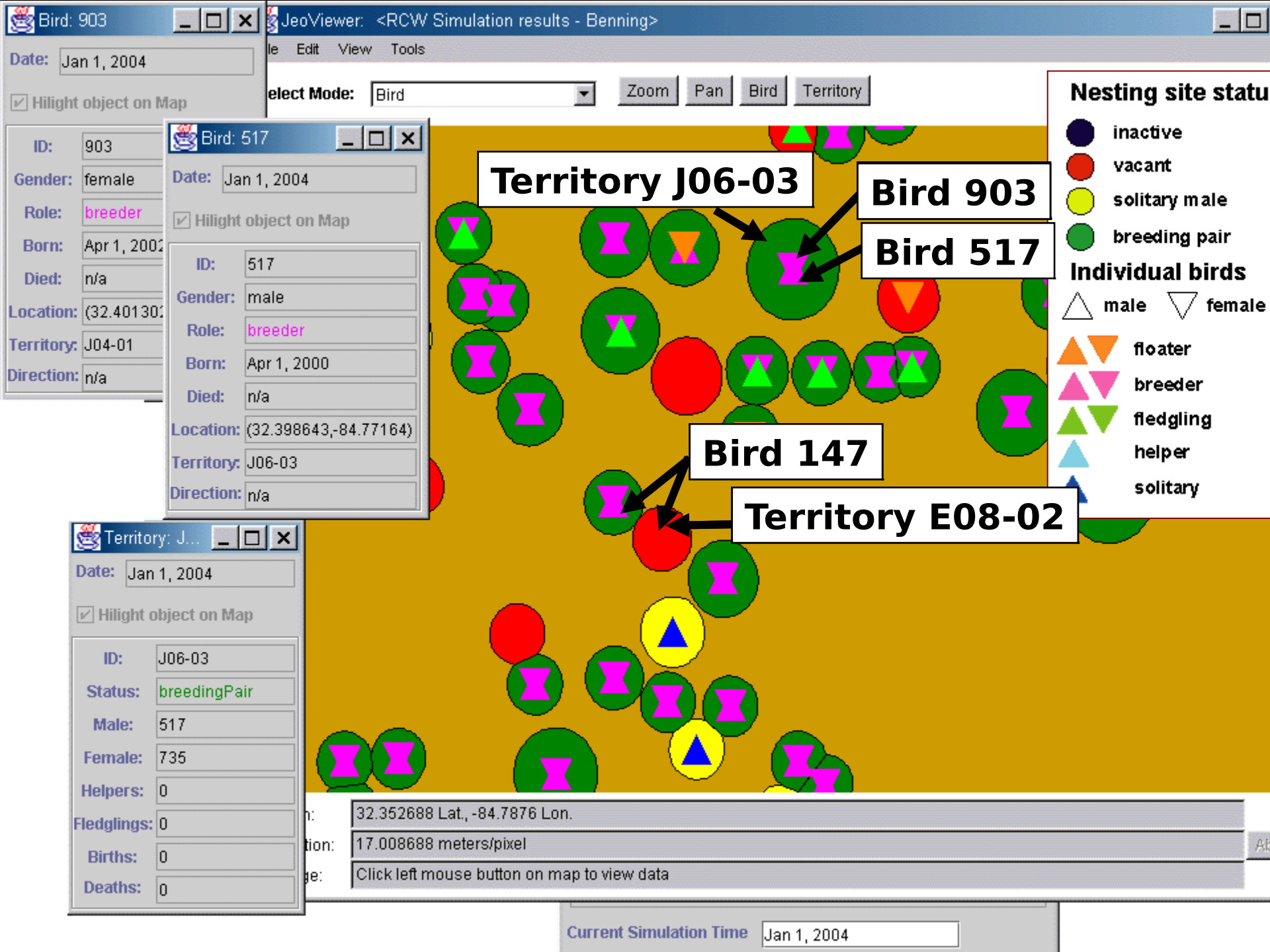
Removal

Model now removes birds annually to reflect "donation" to other recovering populations

Brief Animation of Example RCW Model Run

- **This animation is of a 4-year simulation**
- **Time steps are seasonal**
  - Breeding behavior occurs in April
  - Fledgling role change behavior occurs in January
  - Mortality, dispersal, and competition behaviors happen every seasonal time step




Bird: 903
Date: Jan 1, 2004
Hilight object on Map
ID: 903
Gender: female
Role: breeder
Born: Apr 1, 2002
Died: n/a
Location: (32.401302
Territory: J04-01
Direction: n/a
Bird: 517
Date: Jan 1, 2004
Hilight object on Map
ID: 517
Gender: male
Role: breeder
Born: Apr 1, 2000
Died: n/a
Location: (32.398643,-84.77164)
Territory: J06-03
Direction: n/a
Territory: J...
Date: Jan 1, 2004
Hilight object on Map
ID: J06-03
Status: breedingPair
Male: 517
Female: 735
Helpers: 0
Fledglings: 0
Births: 0
Deaths: 0
JeoViewer: <RCW Simulation results - Benning>
le Edit View Tools
elect Mode: Bird
Zoom
Pan
Bird
Territory
Territory J06-03
Bird 903
Bird 517
Bird 147
Territory E08-02
Nesting site statu
inactive
vacant
solitary male
breeding pair
Individual birds
male
female
floater
breeder
fledgling
helper
solitary
32.352688 Lat., -84.7876 Lon.
17.008688 meters/pixel
Click left mouse button on map to view data
Current Simulation Time
Jan 1, 2004

Benefits of an OO Approach to Model Integration

- **Dynamics:**
  - Allows the simulation to reflect the dynamics of living ecosystems, land uses, and land management activities
- **Reusability:**
  - Allows for the integration of existing legacy-type models without a lot of reworking
  - Encourages the development of object libraries that contain a large number of reusable objects to represent a wide variety of natural and artificial elements of the environment
  - Reduces the long-term cost of re-developing objects and technologies
- **Flexibility:**
  - Easily evolves, incorporating new data, concepts, and technologies
  - Supports software applications that can operate at multiple spatial and temporal scales